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Methods for Removal of Lead Paint From Steel Structures

by

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GT	Geotechnical	EI	Environmental Impacts
HY	Hydraulics	OM	Operations Management
CO	Coastal		

COVER PHOTOS:

TOP - Workers exiting containment structure through an airlock.

BOTTOM - Containment structure covering service bridge and tainter gate on Ohio River.

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Because of the environmental problems leaded paint can create, regulations have been enacted to help protect the environment and the safety and health of workers. However, these regulations have had a significant impact on the cost of painting, on painting with leaded paints, and on the removal of these paints. New methods have been developed to deal with the removal of leaded paints, and the costs of these methods vary, sometimes considerably, with the structure involved and the removal method used. Many field personnel are not familiar with the issues involved with leaded paint removal, the options available, and costs.

This report was prepared to provide information about the current regulations for the removal of leaded paints, new methods of paint removal, and the costs associated with these new methods.

Coating removal methods discussed include: dry abrasive blasting, water jetting, water blasting with abrasive injection, power tool cleaning, and chemical stripping. Maintenance painting methods discussed include spot surface painting, hand or power tool cleaning, vacuum blasting, water blasting, and chemical stripping.

This report focuses on leaded paint on steel structures; removal of leaded paint from other substrates may or may not be done by methods described here.

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PREFACE

This study was authorized by Headquarters, U.S. Army Corps of Engineers (HQUSACE), as part of the Electrical and Mechanical problem area of the Repair, Evaluation, Maintenance, and Rehabilitation (REMR) Research Program. The work was performed under the Civil Works Research Unit 32660, "Removal of Lead Pigmented Paints from Hydraulic Structures" for which Mr. Alfred D. Beitelman is the principal investigator. Mr. John Gilson (CECW-EE) is the technical monitor for this work.

Mr. William A. Rushing (CERD-C) is the REMR Coordinator of the Directorate of Research and Development, HQUSACE; Mr. Jim Crews and Mr. Tony C. Liu (CECW-EG) serve as the REMR Overview Committee; Mr. William F. McCleese, U.S. Army Engineer Waterways Experiment Station, is the REMR Program Manager; Mr. Alfred D. Beitelman is the Problem Area Leader for the Electrical and Mechanical problem area.

This work was conducted by the U.S. Army Construction Engineering Research Laboratories (USACERL) under the general supervision of Dr. Paul Howdyshell, Chief of Engineering and Materials Division (FM), Infrastructure Laboratory (FL). The technical editor was Agnes Dillon, Information Management Office.

This report was prepared under USACERL contract DACW88-93-M-0439 with Corrosion Control Consultants & Labs. The research was conducted by Dr. Lloyd Smith.

LTC David J. Rehbein is the Commander and Acting Director of USACERL, and Dr. Michael J. O'Connor is Technical Director.

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CONVERSION FACTORS, NON-SI TO SI (METRICS)
UNITS OF MEASUREMENT

Non-SI units of measurement used in this report can be converted to SI (metric) units as follows:

Multiply	By	To Obtain
square feet	0.09290304	square metres
gallons	3.785412	litres
feet	0.3048	metres
inches	0.0254	metres
ounces	28.34952	grams
pounds per square inch	6.894757	kilopascals
cubic feet per minute	0.000471947	cubic metres per second

METHODS FOR REMOVAL OF LEAD PAINT FROM STEEL STRUCTURES

PART I: INTRODUCTION

Background

1. Concern over lead-containing paint in the past several years has resulted in the enactment of several environmental, safety, and worker health regulations. These regulations have had a significant impact on the cost of painting. The regulations address various aspects of painting operations, and their impact is far reaching at the painting project level. New methods and strategies have been developed to deal with lead paint removal. Many field personnel are not familiar with the issues involved with lead paint removal, the different options available, and the associated costs.

Purpose

2. This report was prepared to assist the engineer in understanding the current regulations relating to the removal of leaded paints and the procedures and costs associated with the various methods of paint removal. The primary emphasis of this study is limited to the removal of leaded paint from steel structures. Removal of leaded paint from other substrates may or may not use methods described in this report, depending on the intent of the removal method and the type of substrate. Removal of leaded paint in housing is regulated by Housing and Urban Development (HUD)* and is not covered in this report.

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*A list of acronyms and abbreviations is shown in the Appendix.

PART II: REGULATIONS

3. Understanding the changes taking place requires an appreciation of the regulations. The regulations which affect lead removal projects will be briefly described.

Waste

4. Debris generated during surface preparation must be collected and properly disposed of. The Resource Conservation and Recovery Act (RCRA) regulates waste disposal. Regulations on hazardous waste can be found in 40 CFR 260-268. The generator is responsible for determining whether a waste is classified as hazardous. The structure's owner is considered to be the generator and is responsible for the waste *in memorium*. Although certain aspects of waste handling may be delegated to the contractor, the U.S. Army Corps of Engineers will always have the long-term responsibility for the waste.

5. Lead and chromium are two of eight metals regulated under RCRA based on toxicity of the waste generated. Toxicity is determined by measuring the leachable concentration of the metal in the waste using U.S. Environmental Protection Agency (USEPA) Method 1311, Toxicity Characteristics Leaching Procedure (TCLP). The current regulatory limit for both lead and chromium is 5 parts per million (ppm) leachable lead concentration. At 5 ppm or above, the waste is classified as hazardous. (Note that the USEPA published a modification [57 FR 21450] of the regulations that would lower the lead concentration to 1.5 ppm and raise the chromium concentration to 10 ppm; however, a final ruling has yet to be published.)

6. If a waste is classified as hazardous, the waste must be handled in accordance with the requirements in 40 CFR 262. If the waste is nonhazardous, it must be handled in accordance with local regulations. A number of states classify lead-containing, nonhazardous waste as a special (industrial, residual) waste that must go to properly designated landfills.

7. The Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and Superfund Amendments and Re-Authorization Act (SARA) are related regulations dealing with releases of hazardous substances into the environment and clean-up of hazardous waste releases. These regulations can be found in 40 CFR 300-373. Lead and lead compounds are listed as hazardous substances. The reportable quantity for a spill of lead is 10 pounds (lb) or more in a 24-hour (hr) period. Poor attention to work practices can trigger a CERCLA violation and further emphasizes the need for proper containment and collection of surface preparation debris.

8. The RCRA, which is the basis for the hazardous waste regulations, also regulates solid waste. Surface preparation debris is categorized as a waste. As such, it is not allowed to fall on the ground and be left in place. This debris must be collected and properly disposed of. Therefore, any painting project, no matter what is present in the debris, will require containment to collect the waste for disposal.

9. It should be recognized that, after a waste has been designated as hazardous under RCRA, various other laws may come into prominence. Such laws may include Federal, state, and local storage, shipping, and disposal regulations. Although these laws will not be considered individually in this report, they may be of considerable significance to specific projects adding to both the paperwork and costs of the job.

Air Quality

10. The Clean Air Act regulates air quality. The National Ambient Air Quality Standards (NAAQS) are found in 40 CFR 50. Two of the six materials regulated, particulates and lead, can be generated during surface preparation. The current limit on particulate matter is 150 microgram per cubic meter ($\mu g/m^3$) of air for particles with an aerodynamic diameter equal to or less than 10 microns (μ). This is determined using a high volume air monitor known as a PM_{10} monitor. The regulatory limit for lead currently is 1.5 $\mu g/m^3$, maximum arithmetic mean averaged over a calendar quarter. The EPA has indicated a possibility that this limit will be lowered to 0.75 $\mu g/m^3$ of air, maximum arithmetic mean averaged over 30 days. Lead concentration in the air is measured using a Total Suspended Particulate (TSP) monitor. Some locales have their own air quality regulations that differ from the Federal regulations.

Water Quality

11. The Clean Water Act, found in 40 CFR 100-149, encompasses a National Pollutant Discharge Elimination System (NPDES), storm water sewers, and releases of hazardous substances. Construction activities require permits if more than 5 acres of land will be disturbed. When the intent is to contain all debris, NPDES permits are not needed. Reportable quantities of spills of lead-containing debris are categorized in the regulation by specific chemical compound. Although none of the compounds listed in the regulation corresponds directly to the chemical composition of the lead in paint, related compounds have reportable quantities of 100 to 5,000 pounds. Other regulatory agencies, especially state or local agencies, have regulations involved with fish, wildlife, or drinking water that are more stringent than the Clean Water Act restrictions. These regulations vary considerably in analytical methods and

levels and must be investigated prior to preparing contract specifications. Local regulations will have the greater impact on painting projects.

Soil

12. No specific regulation defines soil contamination. The USEPA is under Congressional mandate to define lead-contaminated soil under Title X (Housing and Community Development Act 1992) by April 1994. Currently, some regulatory agencies have used the USEPA Office of Solid Waste and Emergency Response (OSWER #9355.4-02, September 1989) as guidance when evaluating a project site. This directive limits soil lead levels to 500 to 1,000 ppm for land intended for residential or recreational use. Because background lead levels in the soil around a structure can be higher than this, it is imperative that background soil samples be taken before work begins. This directive also points out the need for adequate containment and housekeeping practices when work is performed.

Worker Health and Safety

13. Occupational Safety and Health Administration (OSHA) Standards 29 CFR 1926 were amended effective June 3, 1993, by adding the new section 1926.62, Lead. Its purpose is to protect workers in construction from exposure to lead. It defines an "action level" of airborne concentration of lead above or below which additional compliance measures are or are not required. It is meant to be cost-effective for employee protection. It also adopts the same Permissible Exposure Limit (PEL) as in OSHA's general industry standard 29 CFR 1910.1025 in accordance with Congress' intention. It requires the contractor to provide many safety and health actions. Among them are a compliance plan, medical surveillance, a respiratory protection plan, protective work clothing, and worker training. The rule in 1926.62 is very detailed and specific, and contractors should thoroughly understand and respect it in order to protect employees and to hold down costs.

PART III: SURFACE PREPARATION METHODS

14. Cost effective coatings maintenance requires an understanding of the surface preparation methods available, capabilities of the procedure, containment requirements, and amount of waste generated. There are various methods of classifying surface preparation methods. The two most common are cleaning (paint removal) versus surface preparation, and high dusting methods versus low dusting methods. Cleaning methods are those which only remove the paint. The options then are to prepare the surface to a higher level of cleanliness or to coat the surface with a compatible paint system. However, in many situations, the surface achieved by coating removal is not acceptable. Contaminants such as rust and mill scale still remain on the surface. Most structures that contain leaded coating systems were not blast cleaned initially, so mill scale will be found on the substrate. Surface preparation methods are those that remove the leaded paint, rust, and mill scale and impart a surface profile in one step. Current technology dictates a cleaned, roughened surface for maximum coating life.

15. Classification by high versus low dusting methods is more appropriate for indicating containment needs and worker exposure. High dusting methods require more complex containment to protect the environment and result in higher exposure to workers. Low dusting methods require less containment and lower exposure to workers.

16. Commercially available surface preparation and cleaning methods include:

- Abrasive Blasting
- Wet Abrasive Blasting
- Vacuum Blasting
- Water Blasting
- Water Blasting With Abrasive Injection
- Power Tool Cleaning To Bare Metal
- Chemical Stripping
- other blasting methods.

Every technique will require containment to contain the debris generated and to facilitate collection for disposal. Containment can be as simple as ground tarps or as complex as highly structured units with negative pressure ventilation systems. Steel Structures Painting Council (SSPC) Guide 6I (March 1992) presents information to assist in specifying containment requirements. SSPC Guide 6I describes containment by the containment enclosure components and ventilation system components.

17. The containment components include:

- containment materials (rigid or flexible)
- air permeability of containment materials (air impermeable or air permeable)

- support structure (rigid, flexible, or minimum)
- joints (fully sealed or partially sealed)
- entryways (fully sealed with airlock, overlapping door tarps, or open seam)
- air make-up points (controlled or open).

18. The ventilation system components include:

- input air flow (forced or natural)
- air pressure inside containment (instrument verification, visual verification, or not required)
- air movement inside containment (minimum air movement specified or not specified)
- exit air flow/dust collection (air filtration required or not required).

19. The components and subcomponents are combined differently to describe five classes of containment (Steel Structures Painting Council, March 1992); Class 1 is the most stringent (and most costly) and Class 5 is the least stringent (and cheapest). The class of containment needed varies by surface preparation method and potential environmental impact. Thus, dry abrasive blasting, which generates a lot of dust, would require a high level of containment; but a lower level of containment would be sufficient for power tool cleaning.

20. The following is a discussion of surface preparation methods with regard to various factors related to performing the work desired and environmental issues.

Abrasive Blasting

Method and productivity

21. Dry abrasive blasting is one of the most efficient methods of surface preparation for total coating removal and is capable of removing all contaminants from the surface, including paint, rust, and mill scale. Abrasive blasting is effective on almost any configuration of steel, including corners, angles, nuts, bolts, rivets, and most complex shapes. The main areas for which abrasive blasting has limited effectiveness is tight spaces, such as between back-to-back angles (for which no technique is fully effective). Abrasive blasting also imparts a surface profile (roughness) into the substrate to promote coating adhesion, and it is one of the most productive methods of surface preparation. There are four industry grades of abrasive blasting: Brush-Off (SSPC-SP7), Commercial (SSPC-SP6), Near-White Metal (SSPC-SP10), and White Metal (SSPC-SP5). Depending on the initial condition of the steel and final cleanliness grade specified, productivity ranges from about 50 square feet (sq ft) per hour to 500 sq ft per hour. For this report, a production rate of 100 sq ft per hour is considered to be a typical cleaning

rate for achieving a Near-White (SSPC-SP10) level of cleanliness. This rate applies to structures composed of I-beams.

22. A number of different abrasives are used for abrasive blasting. The most typical are expendable abrasives, i.e., sands and slags. Recyclable abrasives such as steel, aluminum oxide, and garnet also can be used. Recyclable abrasives minimize the amount of waste generated because the usable abrasive is reclaimed for reuse. Recyclable abrasives do not pulverize as much as expendable abrasives. Less dust is generated because the contribution to the dust from the breakdown of the abrasive particles is less than expendable abrasives. The recyclable abrasive most commonly used in the open abrasive blasting mode is steel grit. Contractors who have used this equipment report a 10 to 20 percent increase in productivity in using steel compared to sands or slags. Whether this increase in productivity is inherent in the process or results from improved worker visibility due to less dust is not known.

23. Technically, steel can be recycled more than 200 times. Practically, there are losses of abrasive due to incomplete recovery from containment or loss of good abrasive in the recycling step. Experience has shown that once these losses are included, the true consumption rate of the abrasive is 0.5 to 1 lb/sq ft. Steel abrasive costs about $350 to $500 per ton, compared to a cost of $25 to $80 per ton for expendable abrasives. With consumption rates of 1 and 10 lb/sq ft, respectively, the cost of the abrasive alone is comparable on a square foot basis.

<u>Containment</u>

24. Containment requirements for dry abrasive blasting are high. A full, tight containment is needed. The minimum containment requirements are SSPC Class 3, which is the lowest class requiring negative pressure and a minimum specified air flow in containment. The permeability of the containment materials will have to be limited to only impermeable materials to meet environmental regulations on air quality, depending on location. Class 1 or Class 2 containment may be necessary in highly sensitive areas.

<u>Waste generated</u>

25. Abrasive blasting generates the highest amount of debris because there is a significant contribution from the abrasive. Depending on the level of surface preparation specified, the condition of the coating system, and the condition of the steel, abrasive consumption is about 3 to 10 lb/sq ft. The amount of paint on a square foot of surface is only a few ounces. The waste generated from removing a coating system with a leaded primer probably will be classified as a hazardous waste. There is no correlation between total lead in a paint film and leachable lead in a debris sample.

26. Methods are available to assure that the waste generated will be classified as nonhazardous. These methods consist of the use of abrasive blast additives. If the material is added prior to generating the waste, the

use of treatment additives is allowed by the EPA and can be performed without any notifications. When the treatment additive is added to a waste after the waste is generated, then it is considered to be a treatment of a hazardous waste. Although such treatment may be allowed in some cases under Federal regulations, it may be prohibited under state statutes. Treatment usually requires notifications and approvals.

27. Abrasive blast additives consist of the use of steel grit or Blastox®.* The addition of G-80 steel grit in the range of 3 to 6 percent results in the waste being classified as nonhazardous when tested by the TCLP method. Rather than perform laboratory tests to determine the proper amount of steel grit to add, the current trend in the industry is to require the addition of 10 percent steel grit to the blasting abrasive. The mechanism by which steel grit reduces the leachable lead concentration is by an oxidation-reduction (plating) reaction which takes place during the TCLP test. However, if the steel rusts before the TCLP test is performed, no elemental iron is present for the plating reaction and a hazardous waste results.

28. The addition of steel is effective for a limited time. When the waste is placed in a landfill, the steel will slowly rust and the lead will not be stabilized. The potential exists for a CERCLA violation, with the U.S. Army Corps of Engineers responsible for the cleanup of the waste site. Abrasive blasting debris obtained from jobs when steel grit was added to the abrasive have been tested for long-term stability by the EPA Multiple Extraction Procedure Test (EPA Method 1320). Results have confirmed that leachable lead increases with successive extractions.

29. Long-term stability can be obtained by treatment of the waste with portland cement. A typical mixture design is 300 lb of waste, 94 lb (one sack) of cement, and 7.5 gallons (gal) of water. Debris stabilized in this manner has had very low leachable lead concentrations (about 0.1 ppm). No increase in leachable lead concentration occurs when the waste is tested through the 10 cycles of the EPA Multiple Extraction Procedure Test.

30. Blastox® is a patented silicate-based abrasive blast additive that is added to the abrasive at 15 to 18 percent by weight. Wastes stabilized with Blastox® have a low leachable lead content, generally about 0.1 ppm. These wastes also have been tested for long-term stability by the EPA Method 1320 and show no increase in leachable lead concentration through 10 cycles. The manufacturers of Blastox® have developed a plan to buy the debris, which is then used as a feedstock for another process. The advantage to this program is that, after the material is converted to the alternate use, the debris is destroyed and loses its identity as a waste. Therefore, there is no

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*The TDJ Group, Dubuque, IA. At the time of this report, Blastox® was the only product available for this use.

long-term liability for the waste. This option is being offered on a limited basis in certain areas of the country.

31. The use of recyclable abrasives greatly reduces the amount of waste collected for disposal. For steel abrasive, the most commonly used in open abrasive blasting, there is about a 90+ percent reduction in the volume of waste generated compared to the use of expendable abrasives. The waste stream from the recycling unit is usually classified as a nonhazardous waste because the residual iron from breakdown of the abrasive is in the waste stream. The long-term stability of this waste is questionable for the same reason as presented in the discussion of steel grit addition to expendable abrasives (see paragraph 27). Portland cement stabilization of this waste is effective. However, at least twice as much water is needed as is required without the added steel.

32. Other recyclable abrasives such as aluminum oxide and garnet can be recycled 5 to 10 times. Although use of these abrasives significantly reduces the amount of waste compared to expendable abrasives, the waste usually is classified as hazardous because there is no reaction between the abrasive and the lead compounds to stabilize the waste.

Equipment requirements

33. Dry abrasive blasting is a common surface preparation method with readily available equipment either currently owned by contractors or from construction equipment rental firms. The major equipment requirements are a compressor, pressurized blast pot, air hoses, blast hoses, blast nozzles, moisture and oil separators, abrasive supply, air-fed blast hood, and breathing air supply. The equipment comes in various sizes, depending on the needs of the project. Blast pots vary in size from one bag units (100 lb of abrasive) to 6 or 8 ton units. The size of the compressor needed depends upon the number and size of nozzles being used. For example, each 1/2 in. blast nozzle requires a minimum of 350 cubic feet per minute (cfm) of air to be productive. The larger blast pots contain multiple outlets, so more than one blaster can be working off the same equipment.

34. Containment will require the use of a dust collector to maintain the negative pressure and ventilate the work area. Commercially available, portable dust collectors range in size from 5,000 to 30,000 cfm. The size of the dust collector needed depends on the size of the containment. Ventilation principles recommend maintaining an air velocity inside containment at a minimum of 35 to 100 feet (ft) per minute, depending on the size of the containment. The dust collector capacity (in cubic feet per minute) can be calculated by multiplying the design air velocity (in feet per minute) by the cross-sectional area of the containment (in square feet). Large, portable dust collectors necessary for painting projects are a relatively new item. Dust collector availability can be in short supply, especially during the busy painting season.

35. Use of recyclable steel abrasive requires specialized equipment. Two types of units are commercially available. One type of unit is self-contained, with the recycling unit (and dust collector), blast pot, and abrasive storage pots all included. The other type of unit consists of a centralized recycling unit, with the recovered abrasive put into storage bins or blast pots. The blasting units are separate units. Blasting with steel requires controlling moisture so the steel does not rust. Air dryers and/or large moisture separators are mandatory to dry the compressed air to keep the steel abrasive from rusting. Multiple nozzles can work off the same equipment if sufficient air capacity is used. Even with the large capital investment for steel recycling equipment, the cost of surface preparation is comparable or cheaper than the use of expendable abrasives when the cost of waste disposal is considered. Cost is discussed later in this report.

Wet Abrasive Blasting

Method and productivity

36. Abrasive blasting with water injection consists of adding water to the abrasive stream. The water can be added externally or internally to the blast nozzle. External addition of water is accomplished using a water ring attached to the end of the blast nozzle. Internal addition is accomplished with equipment that either adds the water just prior to the blast nozzle (radially or coaxially), or by other specialized equipment that creates a water/abrasive slurry. Radial water injectors typically use 3 to 5 gal per minute (gal/min), coaxial water injectors use 0.5 to 1 gal/min, and slurry blasters use 0.5 to 4 gal/min.

37. As with dry abrasive blasting, wet abrasive blasting removes paint, rust, and mill scale and is capable of achieving high levels of steel cleanliness. Wet abrasive blasting also imparts a surface profile into the steel and can be used to clean complex shapes as well as flat surfaces. Wet abrasive blasting also has the advantage of removing soluble salts that accelerate corrosion reactions. Another advantage of wet abrasive blasting is it minimizes the dust generated. Productivity of wet abrasive blasting methods is equal to or just slightly less than dry abrasive blasting. However, cleanup time is increased because wet abrasive and debris stick to the steel surface and must be washed off, and they are more difficult to pick up.

38. The safety of those working in an area with wet abrasive is an important consideration. Wet abrasive and debris provide poor footing, and workers can easily slip. A safe, sturdy platform is needed. Wet steel corrodes; therefore, a rust inhibitor must be used. The rust inhibitor either can be added to the water or sprayed on the surface as a separate step. The

rust inhibitor must be compatible with the coating system applied. The coating manufacturer must be contacted to obtain this information.

Containment

39. Containment requirements for wet abrasive blasting methods are less stringent than dry abrasive blasting methods. The water suppresses the dust generated, and the probability of exceeding NAAQS in the surrounding environment is diminished. An SSPC Class 4 containment system with water impermeable tarps most likely is sufficient. A Class 3 containment would be the maximum required.

40. The water used in wet abrasive blasting complicates the containment system because the water needs to be captured. For units that use a low volume of water (i.e., 0.5 to 1 gal/min), most of the water evaporates or is taken up into the debris to form a sludge. However, removing the wet abrasive from steel requires washing, which will generate additional water. This water must be contained and collected and requires a water-tight containment, especially for work in the air. Little field experience has been obtained on the design of this type of containment.

Waste generated

41. Wet abrasive blasting generates large amounts of debris because there is no significant reduction in the amount of debris compared to dry abrasive blasting. The waste from removing leaded coating systems probably will be classified as a hazardous waste. Any water that does not evaporate also must be disposed of. Tests performed to date on wet methods of coating removal have shown that the water contains lead. However, if the water is filtered through a 5 μ filter, the lead level is reduced significantly to a point at which the lead level in the water is below storm sewer limits. The lead can be removed by filtering, which shows that the lead is present in the water as insoluble, particulate matter.

42. Mixing steel grit in with the abrasive is not an effective method of generating a nonhazardous waste because the steel will rust. At best, only short-term stabilization will occur. A preliminary investigation of the addition of Blastox® to abrasive used for wet abrasive blasting resulted in a nonhazardous solid waste. However, the water contained lead that could not be removed by filtering, and the water was classified as a hazardous waste.

Equipment requirements

43. The equipment needed for wet abrasive blasting is similar to dry abrasive blasting, including a compressor, blast pot, blast hoses, nozzle, air-fed blast hood, and breathing air supply. A water ring is an inexpensive device. The only other equipment needed is a container for the water, pump, and water hose. All the other wet abrasive blast units require special equipment that generally is self-contained. The feed mechanisms and controls are included in the unit. Some units will accommodate more than one blaster; other units will not.

Vacuum Blasting

44. Vacuum blasting is identical to dry abrasive blasting with localized collection of the debris through a shroud around the nozzle. The shroud has a brush head that is held up against the surface. The abrasive impinges on the surface, and the debris generated is carried through a hose connected to the shroud to a container or recycling unit. Because vacuum blasting is a form of abrasive blasting, rust, mill scale, and paint can be removed and a surface profile imparted into the surface.

45. Configuration of the structure is an important consideration when evaluating whether or not vacuum blasting is a viable alternative. Proper use of vacuum blasting requires intimate contact between the blast head and the surface. It works best on flat surfaces. Special brush attachments are needed to do inside corners, outside corners, and edges. Surface preparation on irregular surfaces such as nuts and bolts can be performed, but this process requires twisting the head and breaking the seal of the shroud, thus defeating the purpose of vacuum blasting. Because the head must be held perpendicular to the surface, 3 or 4 feet of clearance is needed to obtain a proper seal due to the size of the shroud and bendability of the blast hose.

46. Productivity of vacuum blasting is relatively slow. Job productivity is about 10 to 15 sq ft/hr on structural steel, with faster rates (about 20 to 30 sq ft/hr) possible on flat surfaces. Part of the reason for the low productivity is that the distance between the end of the blast nozzle and the surface is fixed, which results in a relatively small blast pattern. Going to a larger nozzle size to increase productivity results in a head assembly that is heavy and difficult to handle. Productivity is also a function of operator fatigue from the resistance of the brush head/vacuum system and the need to rework areas because the blaster cannot see the results of his efforts until the head is removed from the work area. With time, the operator gains experience and knows how far to move the head between passes.

Containment

47. Containment requirements for vacuum blasting are low. Technically, containment is localized at the head of the tool so no additional containment should be necessary. Practically, a small amount of abrasive or debris escapes when blasting is halted, and a small slug of debris falls to the ground. Also, dust and debris will escape when the seal between the shroud and substrate is broken. This occurs when attempting to clean complex shapes or when the operator twists the head or pulls it away from the surface. A small slug of abrasive or debris escapes each time the blasting is started and stopped. Ground tarps under the work area usually are sufficient to catch the large particulates. Some side tarps also may be needed on structures with complex shapes.

Waste generated

48. The amount of waste generated depends on the abrasive used. Expendable abrasives will generate large quantities of waste similar to open abrasive blasting. Vacuum blasting units contain separators and dust collectors; therefore, the use of recyclable abrasives is appropriate. Steel, aluminum oxide, and garnet commonly are used. The waste generated from removing leaded paints using steel abrasive has a high probability of generating a nonhazardous waste. The long-term stability of this waste was discussed in the section on dry abrasive blasting (see paragraph 27). Debris from removing leaded paints with aluminum oxide and garnet probably will be classified as a hazardous waste. No information could be found on the use of abrasive blast additives in conjunction with vacuum blasting to generate a nonhazardous waste.

Equipment requirements

49. Vacuum blasting equipment comes as a complete, closed recycling system or for use with a standard blast pot. The complete system consists of a blast pot, abrasive recycling system, dust collector, blast and vacuum hoses, and specially designed head. Other systems that can be used with a standard blast pot include the blast and vacuum hoses, special head, vacuum system, collection vessel, and dust collection vessel/filter. A supply of head brushes designed for different configurations is needed. Air drying equipment also is needed, especially for self-contained units, so the abrasive can be kept dry. Air requirements are greater with vacuum blasting because additional air is needed for the vacuum system. For example, dry abrasive blasting with a 3/8-in. nozzle (#6) requires 175 cfm, and vacuum blasting with the same size nozzle requires about 600 cfm. Workers do not require a Type CE blast helmet, but some level of respiratory protection for lead exposure is needed because practical operation of the equipment can result in lead exposures above the OSHA PEL.

Water Blasting

Method and productivity

50. Water blasting is a method of surface preparation in which pressurized water is used to perform the cleaning. A number of different systems are available, each with its own capabilities. The National Association of Corrosion Engineers (NACE) has developed a classification system for water-cleaning methods based on the pressures used. These are: low pressure water washing (up to 5,000 pounds per square inch [psi]), high pressure water cleaning (5,000 to 10,000 psi), high pressure water jetting (10,000 to 25,000 psi), and ultra-high pressure water jetting (above 25,000 psi). Low pressure water washing is intended for removing dirt, grime, soil, and foreign matter. High pressure water cleaning also removes loose rust,

loose coating, and loose mill scale. High pressure water jetting and ultra-high pressure water jetting can remove all paint, but they will not remove mill scale or impart a surface profile into the steel. Either type of unit can achieve a final surface similar in definition to a Commercial Grade Cleaning (SSPC-SP6), except that mill scale will remain on the surface. Ultra-high pressure units are recommended to achieve an appearance similar to a Near-White (SSPC-SP10) or White Metal (SSPC-SP5) grade. Pressures greater than 35,000 psi are needed to remove tightly adherent mill scale, but the rate of removal is extremely slow and not practical.

51. The productivity of water blasting units depends on a number of factors, including type and condition of the existing paint, and the configuration of the structure. A proper distance from the surface must be maintained. High pressure water cleaning usually is performed with the nozzle held about 2 to 10 in. from the surface. Water jetting units usually are most effective when held 0.25 to 0.5 in. from the surface. The energy of the water, hence productivity, drops dramatically with distance from the surface. Maintaining the proper stand-off distance is critical. Water jetting units are most productive when the head is perpendicular to the surface. The lance is usually a few feet long, so it is difficult or impossible to use the equipment in tight spaces. Water units require about 1 to 15 gal/min of water; the ultra-high pressure units require the least amount of water. The more water used, the greater the thrust and hence the greater the operator fatigue. When properly used, the production rate of ultra-high water jetting units is approximately one-third to one-half the production rate of dry abrasive blasting to achieve the equivalent of a Near-White (SSPC-SP10) level of cleanliness, although the mill scale is not removed and the steel is not profiled.

52. Water cleaning methods are most useful when chemical contaminants such as salt are present in the steel. Removing these contaminants extends the life of a coating system. Because water jetting methods cannot effectively remove mill scale or impart a surface profile in the steel, they are more appropriate for situations in which the steel surface is known to have been blast cleaned previously. Rust inhibitors must be used when cleaning to bare metal no matter which method is used. The coating manufacturer must be consulted to determine if the coating material is compatible with the rust inhibitor.

Containment

53. Containment requirements for water blasting methods are mainly for controlling and catching the water and paint chips generated during cleaning. Little dust is generated by these processes, so extensive containment for air quality is not warranted. The water suppresses any dust generated, worker exposure is minimized, and a ventilation system is not needed for the containment. Adequate containment can be obtained with water impermeable

containment materials with partial seams and an open seam entryway (SSPC Class 5). In environmentally sensitive areas or areas in which the public is in close proximity, fully sealed joints and an overlap entryway are preferred (SSPC Class 4). The difficulty with construction of containment is catching and retaining the water generated. A water-tight floor is needed for containments constructed in the air. A method for containing and handling the water is needed for containments that extend to the ground.

Waste generated

54. The waste generated will consist of water and paint chips. No additional materials such as abrasives are used, so the amount of solid waste will be minimal. The amount of solid waste will be only 1 or 2 oz from each square foot of surface cleaned. The solid waste probably will be classified as a hazardous waste when leaded coating systems are removed. Local regulations may require retaining and testing the water prior to disposal. Because the lead is present as solid particulates and is not soluble in neutral pH waters, filtering of the water should be sufficient. The filtered water could be reused for the water blasting and not disposed of until the project is completed.

55. If the water must be retained and tested before either reuse or disposal, provisions must be made for retaining the water. Because the units use 1 to 15 gal of water per minute, depending on the manufacturer, the amount of water needed (and waste water generated) would be between 300 and 5,400 gal per day per unit. Depending on how quickly laboratory analysis results can be obtained, several days of accumulation may need to be retained. Containers will be needed to hold the thousands of gallons of water. If the filtered water must be held until the laboratory results are available, the container requirement doubles.

Equipment requirements

56. Water blasting requires specialized pumps or intensifiers to obtain the high pressures needed for cleaning. High pressure lines are needed to transfer this pressurized water to the tool. The tool itself consists of a lance and nozzle assembly. The water exits through nozzles with small orifices. On the ultra-high pressure units, the nozzles are on a rotary assembly to give a reasonably sized "blast" pattern. A large supply of water and a system to add inhibitor to the water are needed. A pump (intensifier) is needed for each worker. The worker does not require a Type CE blast hood, but facial protection is needed to protect the worker from rebounding water.

Water Blasting with Abrasive Injection

Equipment and productivity

57. Water blasting with abrasive injection consists of a water blasting unit with the abrasive injected into the water stream near the nozzle. The

purpose of the abrasive is to increase productivity, remove tightly adherent contaminants such as mill scale, and impart a surface profile. Production rates are intermediary between the water blasting method used and dry abrasive blasting, or about 75 percent of the rate of dry abrasive blasting. The method is fairly effective on complex shapes and hard to reach areas because the abrasive contributes significanctly to the cleaning. The operator must have sound, safe footing because wet abrasive and debris are quite slippery. Swinging stages and bosun chairs are not acceptable scaffolding. Therefore, water blasting with abrasive injection, as abrasive blasting with water injection, is not applicable to all structures. Expendable rather than recyclable abrasives are used. A corrosion inhibitor is required because this is a wet method.

Containment

58. Containment requirements are based on collecting the water and debris generated. The water limits the dust from the abrasive so a ventilation system is not needed for either environmental or worker protection reasons. The difficulty will be in collecting the water if it needs to be retained for testing prior to disposal. Containments meeting SSPC Class 4 should be sufficient, with full seals on joints in environmentally sensitive areas.

Waste generated

59. Water blasting with abrasive injection uses about one-quarter the amount of abrasive compared to dry abrasive blasting. Therefore, the amount of waste generated is significantly reduced compared to dry abrasive blasting. The waste from removing leaded paints probably will be classified as a hazardous waste. The water also may be a hazardous waste due to very fine particulates. Filtering the water through a 5 μ filter should remove those particulates and result in total lead levels in the water below any storm water sewer standards.

Equipment requirements

60. The basis of the process is water blasting and consists of the equipment described in paragraph 49. In addition, an abrasive hopper/metering system is needed to feed the abrasive to the lance of the tool. The abrasive feed mechanism generally is included in the basic equipment for the process. Each worker will require a complete unit.

Other Blasting Methods

61. Other blasting methods are commercially available but have had limited use in lead paint removal. These methods are sodium bicarbonate blasting, sponge blasting, and carbon dioxide blasting.

Sodium bicarbonate blasting

62. Sodium bicarbonate, or baking soda, is formed into pellets of abrasive size and is used as a cleaning media with wet abrasive blasting equipment. After impinging on the surface, the sodium bicarbonate pulverizes and dissolves in the water. Sodium bicarbonate is relatively soft. Therefore, it is capable of removing only the paint. Expendable abrasives such as mineral sands or slags can be mixed with the sodium bicarbonate when it is necessary to remove mill scale and rust. A typical mix consists of 15 lb sand and slag and 100 lb of sodium bicarbonate. Containment for sodium bicarbonate blasting is similar to that required for water blasting. If another abrasive is added to the sodium bicarbonate, the discussion on wet abrasive blasting would apply (see paragraph 35). Other concerns, such as collection of the water for testing prior to disposal, apply to this method.

63. The amount of waste generated is small when sodium bicarbonate alone is used because the sodium bicarbonate dissolves in the water, and there is no contribution from the abrasive. The waste most likely will be classified as nonhazardous due to residues of sodium bicarbonate mixed in or on the paint chips. Wastes of leaded paint treated with sodium bicarbonate generate a nonhazardous waste due to pH control during the TCLP extraction. However, there would be no long-term stability to the waste in a landfill because water percolating through the mass eventually would wash away any residual sodium bicarbonate coating the particles. The waste should be considered similar to paint chips obtained from water blasting. The amount of debris is increased if an expendable abrasive is added to the sodium bicarbonate.

Sponge blasting

64. Sponge blasting uses a special sponge media to perform the cleaning. Different sponge blast media are available. Straight sponge is effective only for removing paint. Other blasting media have the sponge formed around different types of abrasive particles such as mineral sand, garnet, or steel grit. These media are capable of removing rust and mill scale and achieve a final surface that meets the SSPC definitions, i.e., Commercial (SSPC-SP6), Near-White (SSPC-SP10), and White Metal (SSPC-SP5). Sponge blasting requires specialized equipment. The abrasive is fed with a screw feed mechanism rather than with a blast pot. The abrasive is recyclable.

65. Less dust is generated when sponge or sponge-coated abrasives are used. The fine dust particles are believed to be adsorbed or absorbed by the sponge. On one job on which personal air monitoring was performed, the blasters were exposed to less lead than workers involved in cleanup and recycling of the abrasive. Limited information is available about production rates. The production rate for sponge-covered steel grit media has been reported to be about the same as dry abrasive blasting with coal slag and about 50 percent for the sponge-covered garnet.

66. Containment requirements for sponge blasting is SSPC Class 4. The area must be surrounded to contain and collect the spent abrasive and debris. The use of partially or fully sealed joints depends on the environmental sensitivity of the surrounding environment and public access to the work site. The waste generated from removing leaded paints probably will be classified as a hazardous waste. Assuming the abrasive can be recycled five times, the amount of waste will be approximately 20 percent of the waste generated by dry abrasive blasting with an expendable abrasive.

Carbon dioxide blasting

67. Carbon dioxide, or dry ice, is formed into pellets and used as the blasting media. Dry ice sublimes at room temperature, which means it goes from a solid to a gas without becoming a liquid. Thus, the spent abrasive pulverizes then vaporizes on blasting. Carbon dioxide is a soft material. The cold temperatures of the dry ice are believed to contribute to the cleaning process by cooling the surface. Either the coating becomes more brittle or thermal shock contributes to the removal process. Carbon dioxide blasting removes only the paint and will not remove rust and mill scale, nor will it impart a surface profile into the steel. Complete removal of the paint is difficult and/or time consuming. Going over the surface in a productive manner leaves thin areas or traces of the old primer. Attempting to remove all traces of old paint is slow or cools the surface to below the dew point so condensation and icing occur. Production rates are about 20 to 30 sq ft per hour to remove the paint to the condition described.

68. Carbon dioxide blasting requires specialized equipment. Carbon dioxide is delivered in liquid form, and a nearby source of liquid carbon dioxide is needed to keep the unit supplied. The liquid carbon dioxide is frozen, extruded, and crushed into abrasive-sized particles. Blasting is performed with a special nozzle at high blast pressures. This requires air compressors larger in size than normally used in abrasive blasting.

69. The paint particles removed by the process are larger than achieved with dry abrasive blasting, and the amount of dust is reduced. A ventilation system on containment is not needed. An SSPC Class 4 containment is sufficient, and fully sealed joints are required in environmentally sensitive areas or if the public is in close proximity.

70. The waste generated by the process is minimal because it consists only of paint chips, loose rust, and loose mill scale. The probability of generating a hazardous waste is high when leaded coating systems are removed.

Power Tool Cleaning to Bare Metal

Method and productivity

71. Power tool cleaning to bare metal is described by SSPC-SP11. The technique uses cleaning media attached to power tools to remove paint, rust,

and mill scale. The final surface has an appearance similar to Commercial (SSPC-SP6) or Near-White (SSPC-SP10) metal blast. The method requires using a variety of cleaning media to achieve the end condition. The media include surface cleaning materials and surface profile producing materials. Surface cleaning materials include nonwoven abrasive wheels and discs, sanding pads, coated abrasive flap wheels, coated abrasive bands, and other coated abrasive devices. Surface profiling tools include rotary impact flap assemblies and needle guns equipped with 2 millimeter (mm) diameter needles. SSPC-SP11 requires a minimum 1 mil surface profile. The choice of media depends on the existing condition of the substrate. Surface cleaning media may be sufficient if the steel was blast cleaned previously and the profile was not destroyed during the cleaning process. Both surface cleaning and profiling media will be required if the original surface still contains mill scale, and multiple passes over the surface with different types of tools will be necessary.

72. Power tool cleaning to bare metal can be performed on complex shapes and in hard-to-reach areas if the proper tool is used. A complete array of tools of different shape, size, and design are available to clean almost any surface. Unfortunately, the norm usually is to have a certain number and type of tools on the job and to try using these tools for all surfaces, rather than obtaining the appropriate tool for the situation. Cleaning rates are generally about 10 to 15 sq ft per hour for air-powered tools. Cleaning rates using electrically powered tools are lower because the equipment is heavier and tends to overheat under continuous use.

73. Power tools also can be purchased with vacuum shrouds around the head of the tool. The shroud assembly is attached to a vacuum line that transfers the debris generated back to a collection vessel. Depending on the manufacturer of the equipment, this vessel can be as large as a 55 gal drum or as small as a unit carried on a back pack (6 gal). The air exiting the collection vessel passes through a high efficiency particulate filter (HEPA) as required by OSHA.

74. The method of obtaining the seal between the tool and the surface varies by tool type. In some instances it is a hard shroud and in others it is a brush head assembly. As with vacuum blasting, the seal of the shroud works best on flat surfaces or with shrouds configured to the work, i.e., corners and edges. The ability to clean complex shapes is limited because of the restrictions of the vacuum shroud. Productivity of vacuum-shrouded power tools is similar to use of the tools without the shrouds.

Containment

75. Power tools mechanically impact the coating and thus generate a fair amount of dust. However, the amount of dust is much less compared to dry abrasive blasting. The concentration of dust has a low probability of exceeding the NAAQS a reasonable distance from the work. SSPC Class 5 containment consisting of air permeable tarps with partially sealed joints

will be sufficient in most instances. In environmentally sensitive areas or work that is in close proximity to the public, impermeable tarps, fully sealed joints, and an overlap entryway to containment may be necessary. However, the environment inside the containment has a high probability of exceeding the OSHA PEL for the workers. Lead concentrations can be high enough in some instances that a half-mask respirator will not provide adequate respiratory protection.

76. Vacuum-shrouded power tools do not have sufficient suction to pull in all paint chips, so ground covers are needed. Improper use of the tools or attempting to clean complex shapes results in some dust escaping, and side shields will be needed in sensitive areas.

Waste generated

77. Power tool cleaning generates a minimal amount of waste because the waste will consist of only paint, rust, and mill scale; there is no contribution from the cleaning media. Therefore, the total amount of waste generated will be only a few ounces per square foot. The waste from removing leaded paint systems probably will be classified as a hazardous waste.

Equipment requirements

78. Power tool cleaning requires specially designed impact tools, such as needle guns and flap wheel assemblies, and rotary cleaning tools with abrasive media disks. A supply of cleaning media of different sizes and shapes is required; these items are expendable so a source for replacement is needed. The preferred tools are air powered, and an air compressor is needed. Each tool requires 10 cfm at about 90 psi. Several workers can be accommodated by a small compressor. Vacuum shrouded power tools are specialized equipment and come with the vacuum shroud attached to the tool. A collection/disposal container is needed and is part of the system. Air requirements are higher with vacuum systems, at about 150 to 200 cfm per tool. Some equipment manufacturers supply systems in which multiple tools can operate off the same vacuum container.

Chemical Stripping

Method and productivity

79. Chemical stripping is a method of removing paint using chemical agents. The stripper is applied to the surface, left in place for an allotted time, then removed by scraping or with pressurized water. Chemical strippers remove only the paint. The process will not remove rust or mill scale nor impart a surface profile. If a clean, roughened surface is desired, further preparation of the surface must be performed. This usually is accomplished with abrasive blasting.

80. Chemical strippers come in two basic categories, alkaline strippers and solvent-based strippers. Alkaline strippers are used mainly on oil-based

paints, although they generally do not work on coatings that contain aluminum flake pigments. Solvent-based strippers are used on other coating types such as epoxies. A new generation of so-called "environmentally safe" strippers is entering the marketplace. These products contain different chemicals than the traditional strippers but act on the same principles. They frequently are slightly more expensive than traditional strippers but also may be slightly more effective. No matter which type of stripper is used, test patches must be placed to determine the amount of time for the stripper to remove the coating. The amount of time depends on the existing coating and ambient temperature and can range from 1 to 12 hr. Application rates usually range frpm 10 to 50 sq ft per gallon. It may be necessary to apply a thin "tack coat" prior to application of the full thickness. Most strippers can be applied by airless spray as well as brushing or troweling. Hand application can be performed at a rate of approximately 100 sq ft per man-hour. Spray application can be performed at about 2,000 to 4,000 sq ft per day. The stripper must be protected from rain and vibration while it is on the surface, and it should not be allowed to dry out. Multiple applications may be necessary, depending on the number and type of coatings on the structure. The stripper is removed after the predetermined amount of time by washing or scrubbing. The surface may need to be neutralized after the stripper and paint are removed, especially for alkaline strippers. The surface will require final washing with clean water, no matter what type of stripper is used.

Containment

81. Containment during application and removal of the stripper is mainly for collection of the debris. This usually consists of ground cover or covers over staging to contain the stripper/paint mixture. To protect the soil from contamination, a ground cover of heavy material is needed because picking up the sludge-like waste may cause simple, thin ground covers to rip. A means for collecting the water during the flushing/scrubber stages also is needed. This may be more involved than anticipated because catching the waste water is not a simple task. If side containment is needed, 6 mil polyethylene sheeting usually is sufficient.

Waste generated

82. The waste generated from chemical stripping may or may not be a hazardous waste. The waste from using alkaline strippers may be classified as a hazardous waste based on its corrosivity, if its pH is equal to or greater than 12.5. The waste from removing leaded paints probably will be classified as a hazardous waste because of its lead toxicity. Lead compounds have increased solubility in alkaline solutions. The lead goes into solution and cannot be removed by filtering. The amount of solid waste generated is about one barrel per 1000 sq ft.

Equipment requirements

83. The equipment needs are minimal for chemical stripping. Application equipment consists of an airless spray unit and/or brushes and trowels. Stripper removal is either by scrapers or a high pressure, low volume water washing unit. A supply of water and a water washing unit is needed for final rinsing. A neutralization step, which can be applied with the water washing unit, is needed for some strippers.

Summary

84. The choice of a surface preparation method for a particular structure depends on a number of factors, including the level of surface preparation desired, configuration and location of the structure, amount of lead in the coating, local regulations, and cost. If a high level of cleanliness is required, i.e., Commercial (SSPC-SP6), Near-White (SSPC-SP10), or White Metal (SSPC-SP5), a method that achieves this requirement in one step is preferred. Methods that remove paint but not mill scale or rust require two steps to achieve the end result, paint removal followed by abrasive blasting. Even after the paint (and lead) is removed, containment will be required to collect the debris generated by abrasive blasting to meet RCRA waste disposal requirements and NAAQS requirements for particulates in the air.

85. The configuration of the structure will have an impact on the surface preparation method. For example, vacuum blasting is the best method when there is a large percentage of flat surface. Complicated geometry and a significant percentage of small pieces of steel will make it technically difficult to achieve the proper seal to the surface. Safety must be evaluated when wet abrasive methods are contemplated because the wet abrasive can cause poor footing; structures that cannot be easily scaffolded so the worker has firm footing are not candidates for wet abrasive methods. The location of the structure is an important consideration. Structures located in or near environmentally sensitive areas or where the public is in close proximity (within 200 ft) require either low dusting surface preparation methods or stricter containments.

86. The amount of lead in the paint film is an indicator of the probability of exceeding regulatory limits. Table 1 was derived in part from material developed by SSPC for a Workshop on Engineering Management of Lead Coated Structures, and it presents guidance for determining the probability of exceeding the pertinent lead-related regulations. The regulations pertain to any coating that contains lead, whether it is in relatively high concentrations such as leaded primers, moderate concentrations such as certain coloring pigments, or low concentrations such as driers in alkyd paints.

87. Local regulations and concerns must be addressed. If minimizing the amount of waste is a primary concern, a method that uses recyclable abrasive or no abrasive is appropriate. Disposal of water should be investigated if a wet method is considered. Other regulations can impact the choice of method. After the site restrictions have been determined, the alternatives can be limited and the cost of the alternatives evaluated.

88. For spot maintenance situations, surface preparation methods that generate small amounts of dust and debris are preferred. Brush-Off blast cleaning (SSPC-SP7), a technique that has been popular in the past, is not cost effective because of the high level of containment needed.

TABLE 1
Correlation Between Risk and Lead Concentration*

Lead in Paint	Method	Exceed Hazarous Waste	Exceed OSHA PEL	Exceed NAAQS at 200 ft
>5%	Blast	High	Very high	High
	Wet	High	High	Low
	Mechanical	Very high	High	Moderate
	Vacuum	High	Low	Very low
1-5%	Blast	Moderate	High	High
	Wet	Moderate	High	Low
	Mechanical	Very high	Moderate	Low
	Vacuum	Moderate	Low	Very low
0.2-1.0%	Blast	Low	Moderate	Low
	Wet	Low-moderate	Moderate	Very low
	Mechanical	Moderate	Low	Very low
	Vacuum	Low	Very low	Very low
0.06-0.2%	Blast	Very low	Low	Very low
	Wet	Very low	Very low	Very low
	Mechanical	Low	Low	Very low
	Vacuum	Very low	Very low	Very low

* This table should be used only as a guide. True determination of the hazard associated with a specific job can only be determined on a case-by-case basis using the prescribed testing procedures.

Part IV: COST

89. There are two methods of determining cost, engineering estimate and job estimate. Engineering estimates are calculated using average rates and costs on a square foot basis to determine the cost per square foot. Multiplying this number by the number of square feet of surface area gives an estimate of the cost of the job. A job estimate is calculated by determining how long it will take to complete the job. The labor cost is determined by calculating the amount of time needed and the number of workers in the various wage categories. Costs are added in for paint abrasive, fuel, and other expendable items. Equipment costs usually are determined on a rental basis. Other miscellaneous costs, overhead, and profit are added.

90. Costs can vary considerably from job to job. The condition of the existing coating and substrate will impact on production rates. Heavily rusted and pitted steel requires more effort per square foot than uncorroded steel. Configuration of the structure is another important factor. Production rates are higher on large, flat surfaces compared to beams and other shapes with changes in angles and positions, or more time is required to clean complicated shapes and tight areas. Labor rates vary throughout the country. Disposal costs for both hazardous and nonhazardous waste also vary throughout the country, and transportation costs depend on the proximity of an acceptable landfill to the job site.

91. The cost information presented in the following sections is based on engineering estimates, with actual costs included when appropriate. The information is based on cleaning structural steel or complex steel, and it is meant for comparative purposes.

Abrasive Blasting

92. Historically, the engineering estimate for coating projects is determined from surface preparation costs, paint application costs, and materials costs. Using this method with 1992 cost data for field painting (Brevoost and Roebuck, April 1993), the estimate for blast cleaning to a Near-White Metal (SSPC-SP10 [SP = surface preparation) and applying a three coat painting system would be:

surface preparation	$1.00/sq ft
paint application	0.90
materials (paint)	0.35
total	$2.25/sq ft

The cost per square foot is multiplied by a difficulty factor depending on height and intricacy. This factor is between 90 percent (simple, easily

reached structures such as ground tanks) and 175 percent (intricate structures or structures over 50 ft high). Therefore, the installed cost for a painting system is between $2 and $4/sq ft.

93. The foregoing cost estimate assumes that containment was not used, the debris was not collected, environmental monitoring was not performed, and no special worker protection requirements were followed. When costs for these factors are included, the estimate becomes:

	Range	Average
cleaning and painting	$2-$4	$2.50
containment	2-6	2.50
disposal	0-3	0.50
environmental monitoring	0-2	0.50
worker health	1-2	1.50
overhead/miscellaneous	0-2	0.50
total	$5-$19/sq ft	$8.00/sq ft

94. Containment costs are approximately $2 to $6/sq ft. The cost of containment depends on the size of containment used, the size of the project, and the complexity and height of the structure. Some contractors use mini enclosures; other contractors prefer to use large enclosures. In most instances the containment is constructed of tarps. High structures require a flooring system or chutes to channel the debris to the ground. Commercially available flooring systems cost between $150,000 and $250,000. More than one flooring system may be required on a large structure. Moving the containment system may take a few hours for a small enclosure to a few days for a large enclosure. Initial construction and moving a containment system costs $0.50 to $2.00/sq ft, depending on the height and complexity of the structure.

95. Negative pressures and ventilation are accomplished with large dust collectors, which cost between $25,000 and $100,000, depending on size. A 20,000 cfm dust collector costs about $70,000. The monthly rental for equipment in the painting industry is about 10 percent of the purchase price. Thus, the rental of a 20,000 cfm dust collector is $7,000 a month. If, for example, the dust collector is operated for 160 hr a month, the hourly rental charge is $44. Operating expenses (fuel and maintenance) are $4 to $5 per hour, resulting in an hourly rate of nearly $50 per hour. Assuming that the blasting production rate is 100 sq ft per hour, the cost of the ventilation system alone is $0.50/sq ft. A normal job will have two or three blasters, which translates to a cost for ventilation of $0.17 to $0.25/sq ft. Lower production rates will increase the cost per square foot of ventilation. The cost of ventilation is comparable to the cost of the coating materials (estimated at $0.35/sq ft).

96. Multiple dust collectors may be needed on a large containment system to maintain adequate air velocity and negative pressure. Smaller structures or simpler structures require smaller containments, less ventilation, and/or are simpler to move. The Ohio Department of Transportation reported that, in 1990, the average cost of containment on eight projects that consisted of painting 31 bridges was $1.50/sq ft. Ohio required the use of air permeable tarps and did not require a ventilation system. Because ventilation systems no longer are an option but a requirement to meet the OSHA lead in construction standard while abrasive blasting, an average cost for containment is estimated to be about $2.50/sq ft. This cost will be lower for simple structures and can be significantly higher for large, high, complex structures.

97. Waste disposal costs depend on the type of abrasive used and the waste classification. Disposal of hazardous waste varies from about $250 to $450 per ton, depending on the amount of waste and how it is packaged. Transportation costs are extra. The cost of disposal of nonhazardous waste varies from about $25 to $80 per ton, depending on local landfill charges. Some states classify a nonhazardous, lead-containing waste as a special waste (also referred to as residual or industrial waste). Disposal fees are similar to nonhazardous waste, but landfills permitted to accept this waste may not be near the project so transportation costs will be greater.

98. Assuming that 10 lb of disposable abrasive are required to achieve a Near-White (SSPC-SP10) and a 90 percent recovery rate, the cost of disposal of hazardous waste will be $1.00 to $2.50/sq ft. The cost for disposal of a nonhazardous waste will be $0.10 to $0.35/sq ft. The use of Blastox® with expendable abrasive will generate a nonhazardous waste. The additional cost of Blastox® mixed in with the abrasive is $100 per ton. This will increase the cost of disposal to $0.60 to $0.85/sq ft.

99. If steel abrasive is used, the cost for waste disposal will be less compared to an expendable abrasive. About 0.5 lb of debris per square foot of surface will be collected for disposal. This calculates to $0.06 to $0.12/sq ft for hazardous waste and $0.01 to $0.02/sq ft for nonhazardous waste. Keep in mind that waste generated with steel abrasive may test to be nonhazardous. However, this waste does not have long-term stability, and disposal as a hazardous waste is recommended.

100. Putting the waste disposal numbers in perspective, the average cost of waste disposal for surface preparation on a 100,000 sq ft structure will be $175,000 for an expendable abrasive classified as a hazardous waste, $45,000 if the waste is classified as nonhazardous (highly unlikely), $72,500 for an expendable abrasive that incorporated Blastox®, and $9,000 for the waste if steel grit is the abrasive. These are average costs. Prices do not include the cost of containers and transportation. Actual costs also are influenced by the amount of waste to be disposed of.

101. Environmental monitoring is part of the cost calculation and includes air monitoring and soil sampling. Different strategies can be used for air monitoring, including monitoring during the duration of the job, monitoring for the first week on a regular basis (i.e., every few months), monitoring only for complaints, or no air monitoring. Air monitoring to meet NAAQS requirements must be performed with a minimum of two sets of high volume air monitors. One of the monitors, a PM_{10}, is used for measuring particulate matter, and a TSP monitor is used to measure lead. A technician is needed to calibrate the monitors, change the filters, and maintain the monitors. A source of power, usually portable generators, also is needed. The availability of high volume air monitors is limited, and few firms own these monitors. Therefore, mobilization/demobilization expenses and living expenses for the technician are involved with air monitoring. When all these charges and costs for laboratory analyses are included, the price for environmental monitoring is $5,000 to $10,000 per week. Because some air monitoring should be performed on each project, an average cost of air monitoring per project is estimated to be $0.50/sq ft.

102. Worker health costs are difficult to estimate because the OSHA Construction Industry Lead Standard just became law. Under this regulation, contractors must provide workers with protective clothing, mandated respiratory protection, and shower/decontamination facilities. They also must supply each worker with medical examinations, respirator fit tests, and regular blood analysis for lead and zinc protoporphyrin. Worker training and written compliance programs are other costs that must be recouped. According to OSHA, the cost of compliance is estimated to be $775 per worker. This estimate may be low, especially for contractors who have not conformed to all OSHA regulations in the past. On large jobs a worker may be assigned to such OSHA activities as cleaning respirators, clothes, equipment, and change/decontamination facilities and monitoring worker compliance. In other situations when leaded paint removal projects were closely evaluated, the contractor may have hired a certified industrial hygienist (CIH) or a firm specializing in lead safety to evaluate their practices and make recommendations. The cost of worker health is estimated to be $1 to $2/sq ft, depending on the size of the project.

103. Overhead and miscellaneous costs also have been included in the calculation. The most notable added item is pollution insurance, if such coverage can be obtained. There also is increased overhead due to recordkeeping functions, especially for OSHA compliance, when employee medical records, air monitoring results, and other information must be maintained. Lead projects also sometimes require added attention from central office staff. Field staff may not be sufficiently knowledgeable on some health and environmental issues, and technical assistance or involvement of the company safety director and technical staff will be required. An added cost of $0 to

$2/sq ft is estimated. The average would be expected to be on the low end, hence $0.50/sq ft was estimated.

104. The foregoing discussions indicate that the cost of meeting environmental and worker health regulations has significantly increased the cost of coating projects. In fact, the cost of meeting these regulations is more than the cost of the work itself. Specifying a Commercial Grade (SSPC-SP6) of surface preparation has minimal cost impact. The average cost of SSPC-SP6 is $0.85/sq ft. Less waste will be generated and result in a savings of $0.01 to $0.10/sq ft. This gives a maximum overall savings of $0.15 to $0.25/sq ft. Conversely, blasting to a White Metal Grade (SSPC-SP5) is about $1.20/sq ft. When the cost for additional disposal is included, the cost the is $0.20 to $0.30/sq ft.

Wet Abrasive Blasting

105. Using the method presented in abrasive blasting, the cost of wet abrasive blasting is estimated as follows:

	Range	Average
cleaning and painting	$3-$7	$4.00
containment	1-6	3.00
disposal	0-3	2.00
environmental monitoring	0-2	0.50
worker health	1-2	1.50
overhead/miscellaneous	0-2	0.50
total	$5-$22/sq ft	$11.50/sq ft

106. Although the production rate of wet abrasive blasting is similar to or only slightly less than dry abrasive blasting, the cost to do the work is more. The basic equipment costs are the same, but some increase will result from a water addition system and corrosion inhibitor. For example, the flash rust inhibitor is estimated to cost $0.05 to $0.10/sq ft. The published estimate (Brevoost and Roebuck, April 1993) for slurry blasting is $1.25/sq ft, compared to dry abrasive blasting at $1.00/sq ft. Using the average cost for dry abrasive blasting for comparative purposes, the average cost for cleaning and painting using wet abrasive blasting is estimated to be about $2.75/sq ft. This cost would apply to ground structures or structures that are easily scaffolded. However, if work is performed in the air with marginal scaffolding, production rates will drop significantly because workers will be more concerned about footing. A 50 percent drop in productivity on a high structure will result in an estimated cost for surface preparation of $2.50/sq ft. Adding the cost of coating application and coating materials, and multiplying

by the height difficulty factor, results in an estimated cost for cleaning and painting of over $6.50/sq ft for high structures.

107. The cost of containment depends on the type of structure and local regulations. Basic containment will consist of a tarp arrangement with partially or fully sealed joints. A ventilation system will not be needed. For a ground level structure in which the water does not have to be collected, this containment will cost about $0.25 to $0.50/sq ft. A fully sealed containment of this sort will cost about $0.50 to $0.75/sq ft. A basic containment constructed in the air will cost about $1.00 to $1.50/sq ft.

108. More complex containment is needed if the water has to be collected for testing prior to disposal. Wet abrasive blasting units generally use little water. The blasting process aids in breaking the water into fine particles and heating it, which promotes evaporation; most of the water evaporates leaving a sludge. However, washing the debris from the surface uses considerably more water, which is not broken into fine particles and collects in puddles. Little field experience has been obtained on containing water from wet abrasive blasting. For structures where the water can fall to the ground, layers of tarps and plastic sheeting will be sufficient. However, for work performed in the air, a leak-proof containment bottom must be constructed. The best cost estimate for this situation is $4.00 to $6.00/sq ft.

109. Only expendable abrasives can be used with wet abrasive blasting. Using the example of 10 lb of abrasive per square foot, the cost of disposal of nonhazardous and hazardous waste is $0.10 to $0.35/sq ft, and $1.00 to $2.50/sq ft, respectively. Blastox® can be used with the abrasive, with a disposal cost of $0.65 to $0.85/sq ft. The cost of collecting the debris must be added to the disposal costs. Wet debris is more difficult to collect and move than dry debris. On a simple ground structure, such as a ground storage tank, washdown of the surface will result in all the debris being deposited on the ground cover so the material can be scooped up and placed in containers. The cost of collection of the debris in this situation is only a few cents per square foot. However, for a complicated structure, such as structural steel or structures with many horizontal surfaces, the manpower necessary for cleanup could be significant. Labor charges could be equal to, or more than, the cost of the paint application, especially if multiple washing steps are involved or debris must be removed manually. The cost estimate is $0.10 to $0.50/sq ft.

110. If the water needs to be collected and disposed of, the cost of disposal of the water must be included. The simplest method is to filter the water through a 5 μ filter and dispose of it directly. A filtering apparatus costs $1,000 to $2,000. Even with replacement filters, the cost to the project is only a few cents per square foot. If the water must be disposed of as a hazardous waste, the cost per drum will be $250 to $500 per drum.

Assuming a gallon of water is used to clean 10 sq ft, the disposal cost of the water is $0.45 to $1.00/sq ft.

111. The range of costs for environmental monitoring, worker health, and overhead/miscellaneous is the same as estimated for dry abrasive blasting. Environmental monitoring, on the average, costs less than dry abrasive blasting. Little visible material will be seen escaping containment. Therefore, EPA air monitoring will not be used in many instances. Only soil monitoring must be performed, and it costs only a few cents per square foot for most structures. Worker exposure to lead is reduced by wet abrasive blasting, but it still is above the PEL. Therefore, the cost of worker health is the same as for dry abrasive blasting. Overhead/miscellaneous costs are not impacted by use of wet abrasive blasting.

112. In conclusion, the cost of wet abrasive blasting is comparable to dry abrasive blasting for simple low structures such as ground storage tanks. The advantages of using this method are lower containment requirements, less visible dust, and lower lead exposures to workers. Costs increase significantly for elevated structures or situations when the water must be collected, retained, and tested prior to disposal.

Vacuum Blasting

113. The cost of vacuum blasting is estimated as follows:

	Range	Average
cleaning and painting	$3-$12	$7.00
containment	0-1	0.00
disposal	0-1	0.25
environmental monitoring	0-2	1.50
worker health	1-2	1.50
overhead/miscellaneous	0-2	0.50
total	$4-$20/sq ft	$9.75/sq ft

114. According to information supplied by one of the vacuum blasting equipment manufacturers (McFee, October 1992), the cost of operating their large units is between $74 and $85 per hour when using steel grit abrasive, and $92 to $134 per hour when using aluminum oxide abrasive. These estimates include equipment costs (including maintenance), abrasives, consumables, compressor (including fuel), and labor (at $25 per hour). Experience has shown that production rates with this size unit vary from 15 sq ft per hour on structural steel to 60 sq ft per hour on flat steel. Using an average operating cost of $80 per hour, the cost of surface preparation will vary from $1.30 to $5.30/sq ft. When materials and painting costs are added and a

difficulty factor applied, the cost estimate of cleaning and painting is $2.55 to $11.50/sq ft.

115. Containment costs are minimal for vacuum blasting because collection of debris is localized at the head of the tool. The main environmental concerns with vacuum blasting are loss of large particulate matter from improper use of the tool and a small slug of abrasive or debris during start-up/shutdown of the tool. Technically, no containment is needed. Practically, a ground or catch tarp under the work area is necessary. When the tool is operated improperly, i.e., the head is not kept in contact with the surface, side tarps also will be needed. But assume that the tool will be operated properly for cost estimate purposes. Either no containment or a ground or catch tarp will be used. The cost associated with either of these arrangements is minimal. (Tarps under the work area are not a major investment in either materials or time.)

116. Disposal costs depend on the type of abrasive used. The two most common abrasives are steel and aluminum oxide. Steel abrasive will generate about 0.5 lb of debris per square foot. Properly used vacuum blasting will collect all this material for disposal. Although the waste will be classified as nonhazardous, the debris does not have long-term stability. Therefore, it should be treated with portland cement or disposed of as a hazardous waste, and the cost will be $0.10 to $0.25/sq ft. If aluminum oxide is used as the abrasive, about 2 lb of debris per square foot will be generated and it probably will be classified as a hazardous waste. The cost of disposal will be $0.25 to $0.50/sq ft.

117. On a practical basis, environmental monitoring costs are zero. When properly used, vacuum blasting is efficient at collecting the dust and debris generated. Visible emissions are minimal so ambient air monitoring will not be required. Soil monitoring is recommended because a small amount of debris usually escapes when the blasting ends and can end up on the ground. Soil monitoring will cost only a few cents per square foot. Technically, there should be no costs for worker health because workers will not be exposed to lead. Practically, some dust does escape because of worker procedures and from handling the debris generated. The possibility exists in a practical situation of workers exceeding the PEL for lead. Therefore, an estimated average cost of $1.50/sq ft is recommended. Overhead/miscellaneous costs are not affected by this process, and an average cost of $0.50/sq ft is recommended.

118. In conclusion, vacuum blasting is cost competitive on structures with a high percentage of large, flat surfaces where the larger machines can can be used. This process saves containment and clean-up costs because these functions are built into the equipment. The use of recyclable abrasives, especially steel grit, also helps to minimize cost. Limitations on proper operation of the equipment, especially on maintaining a proper seal of the

blast head to the surface, result in low production rates on small, structural steel members, and vacuum blasting then becomes more expensive or technically unfeasible.

Water Blasting

119. The cost of water blasting is estimated as follows:

	Range	Average	To SP-10
cleaning and painting	$3-$6	$4.00	$5.50
containment	0-1	3.00	4.50
disposal	0-1	0.00	0.25
environmental monitoring	0-2	0.00	0.00
worker health	1-2	1.50	1.50
overhead/miscellaneous	0-2	0.50	0.50
total	$4-$20/sq ft	$9.00/sq ft	$12.25/sq ft

120. The estimate for cleaning and painting was developed based on a production rate that was 50 percent of dry abrasive blasting. The equipment and blasting media costs for dry abrasive blasting and water blasting were judged to be of equal magnitude. In one instance, a special water-blasting pump, lance, and water are needed. Dry abrasive blasting requires a compressor, blast pot, and abrasive. At half the production rate, the cost of surface preparation is $2.00/sq ft. Adding in paint materials and application, and multiplying by the difficulty factor, gives a range of $2.90 to $5.70/sq ft.

121. The cost of containment depends on the type of structure and local regulations. Basic containment consists of a tarp arrangement with partially sealed or fully sealed joints. For a ground level structure, this containment will cost $0.25 to $0.50/sq ft. A fully sealed containment will cost about $0.50 to $0.75/sq ft. A basic containment constructed in the air will cost about $1.00 to $1.50/sq ft. A basic problem is containment of the water and paint chips. There is little experience to give guidance on this cost. For ground level containment, a berm or a depression is needed so water does not run off. Containments in the air have to be leakproof and require a device to channel the water and chips to a container below. Depending on the structure and design of containment, this cost is estimated to be $0.50 to $6.00/sq ft.

122. The amount of solid debris collected will be minimal. A typical structure has about 1 to 3 oz of coating per square foot. The paint chips probably will be classified as a hazardous waste. Using an average of 2 oz of coating per square foot, the cost of disposal of the debris will be $0.01 to $0.03/sq ft. Collecting the paint chips for disposal also must be considered; this will require a filtering step. The cost of a 5 μ filtering assembly and

its operation will increase the disposal cost by a few cents. The cost of disposal becomes extremely high if the water must be disposed of. Units capable of removing all paint operate in the 10,000 to 50,000 psi range and use between 1 and 14 gal of water per minute. At a production rate of 50 sq ft per hour, the water usage is 1.2 to 16.8 gal per square foot. Using a disposal cost of $400 per 55 gal drum, the disposal cost is $8.75 to $122/sq ft. On a practical basis, the lead is present in the water as particulate matter and should be capable of being removed by filtering. Therefore, disposal costs will be about $0.05 to $0.10/sq ft. Disposal of the water is extremely expensive; therefore, filtering of the water must be addressed prior to any work with the local environmental agencies.

123. On a practical basis, environmental monitoring costs will be zero. Water is effective at minimizing dust and visible emissions, so air monitoring is not required. Soil sampling is highly recommended because there is concern about ground contamination from leakage. However, the cost of soil sampling results in a minimal increase in cost per square foot for most structures. Insufficient information is available from personal air monitoring to determine if any worker category will be exposed above the PEL. Because the PEL is so low, it may be possible to exceed this limit even with water blasting. Overhead/miscellaneous will not be impacted by the use of water blasting.

124. Water alone will not remove mill scale and will not impart a surface profile into the steel. Many existing structures that contain leaded coatings were not initially blast cleaned, so a comparison of the cost of water blasting to dry abrasive blasting must include achieving the same surface cleanliness. The cost of surface preparation is $1.00/sq ft. When a difficulty factor is included, the cost is $1.00 to $2.00/sq ft. Containment will be needed to collect the debris. Also, NAAQS for particulates can be exceeded when dry abrasive blasting. A containment with 85 percent screen should be sufficient, and no dust collector/ventilation system will be needed. The cost for containment for meeting these requirements is estimated at $1.50/sq ft. The waste generated will be nonhazardous. An expendable abrasive probably will be used. There would not be a significant difference in the amount of abrasive used compared to complete removal by dry abrasive blasting because most of the energy in dry abrasive blasting is expended on removing the mill scale. Therefore, disposal costs will be about $0.25/sq ft. Environmental monitoring costs will be for particulates only. Practically, this monitoring most likely will not be performed, except in the most sensitive areas. No additional costs for environmental monitoring have been included. There will not be an additional cost for worker health or overhead/miscellaneous because the coating will have been removed and lead will not be an issue.

Water Blasting with Abrasive Injection

125. The cost of water blasting with abrasive injection is estimated as follows:

	Range	Average
cleaning and painting	\$2-\$5	\$4.00
containment	1-7	5.00
disposal	0-1	1.00
environmental monitoring	0-2	1.50
worker health	1-2	1.50
overhead/miscellaneous	0-2	0.50
total	\$4-\$19/sq ft	\$13.50/sq ft

126. Using a production rate of 75 percent of dry abrasive blasting, the cost of surface preparation is about \$1.35/sq ft. Hence, the cost of cleaning and painting is \$2.50 to \$5.00/sq ft. Because production rates are based on good footing for worker safety, the average cost is estimated to be on the higher end of the range.

127. The cost of containment depends on the type of structure and local regulations. Basic containment will consist of a tarp arrangement with partially or fully sealed joints. For a ground level structure when water does not have to be collected, this containment will cost \$0.25 to \$0.50/sq ft. A fully sealed containment constructed in the air will cost \$1.00 to \$1.50/sq ft.

128. More complex containment will be needed if the water needs to be tested prior to disposal. Water blasting with abrasive injection typically is performed with units which use 5 to 10 gal/min of water. One hour of operation by one unit will generate 300 to 600 gal of water. The containment must be water tight. Ground level containments must be built up or depressed in sufficient size to hold the large amounts of water generated in a day. Containments in the air must be sturdy enough to support the weight of the water. The option is to remove the water either by channeling or pumping it to a holding area or tanks.

129. The containment also must hold the blasting debris generated. Wet blasting with abrasive injection uses about one-quarter the amount of abrasive as dry abrasive blasting, which results in 2.5 lb per square foot, or about 200 lb per hour per unit. Little field experience has been obtained on the design and construction of containment when all the debris (liquid and solid) must be collected. The best estimate is \$5.00 to \$7.00/sq ft.

130. Only expendable abrasives are used for water blasting with abrasive injection. Using the example of 2.5 lb of abrasive per square foot, the cost of disposal of nonhazardous and hazardous waste is \$0.03 to \$0.10/sq ft and

$0.30 to $0.55/sq ft, respectively. The cost of collecting the debris must be included in the disposal cost because it is difficult to gather and move damp debris. The cost estimate derived for collection of debris for wet abrasive blasting was $0.10 to $0.50/sq ft. Therefore, the total disposal cost is $0.13 to $0.60/sq ft for nonhazardous waste and $0.40 to $1.05/sq ft for hazardous waste. Because it is highly probable a hazardous waste will be generated from a structure coated with leaded paint, the average estimated cost is $1.00/sq ft. If the water needs to be collected and disposed of, the cost of disposal of the water must be included. The simplest method is to filter the water through a 5 μ filter and dispose of it directly. A filtering apparatus and its operation costs only a few cents per square foot. If the water must be disposed of as a hazardous waste, the cost is $250 to $500 per drum. At 5 to 10 gal/min and a cleaning rate of 75 sq ft per hour, the disposal cost for the water will be an additional $18 to $70/sq ft!

131. The range of costs for environmental monitoring, worker health, and overhead/miscellaneous is the same as estimated for dry abrasive blasting. On the average, environmental monitoring will cost less than dry abrasive blasting. Little visible material will be seen escaping containment. Therefore, EPA air monitoring will not be used in many situations. Only soil monitoring must be performed, and this will cost only a few cents per square foot for most structures. Worker exposure to lead will be reduced compared to other blasting methods, but insufficient data exists about whether the exposure will be above or below the PEL. Therefore, the cost of worker health is assumed to be the same as for dry abrasive blasting. Overhead/ miscellaneous costs will not be impacted by used of wet abrasive blasting.

Power Tool Cleaning to Bare Metal

132. The cost of power tool cleaning to bare metal is estimated as follows:

	Range	Average
cleaning and painting	$4-$7.50	$6.00
containment	0-1	1.00
disposal	0-0	0.00
environmental monitoring	0-2	1.50
worker health	1-2	1.50
overhead/miscellaneous	0-2	0.50
total	$5-$14.50 sq ft	$9.00/sq ft

133. Power tool cleaning to bare metal is labor intensive as opposed to equipment intensive. Basic equipment cost is only a few thousand dollars, expendables are less than $1 per hour, and compressor requirements are low.

With a labor charge of $25 per hour and a typical crew of four workers and one relief man, the project labor charge is $31.25 per tool hour. After equipment charges, compressor, fuel, and so forth are added in, a project labor rate of $35 per tool hour is reasonable. But the average hourly cost will be higher if local labor rates are higher. Available information indicates that production rates vary from about 10 to 15 sq ft per hour on flat steel, i.e., a ground storage tank. This results in a cost for surface preparation in the range of $1.40 to $3.50/sq ft. Recent cost data in the literature (Lefkowitz and Taylor, March 1990; Bloemke, March 1990) indicates surface preparation costs of $2.95 (with disposal) and $3.04/sq ft for easily accessible jobs. Therefore, a basic surface preparation of $3.00/sq ft was used. Adding in paint material costs and multiplying by the difficulty factor gives an estimate of cleaning and painting costs in the range of $4.00 to $7.50/sq ft.

134. Containment costs are based on the use of an SSPC Class 4 containment. This was previously estimated to cost $0.25 to $0.50/sq ft and the cost increases to $0.50 to $0.75/sq ft if full seals are required and $1.00 to $1.50/sq ft if constructed in the air. If vacuum power tools are used, ground or catch tarps are recommended because material can escape if tools are not used properly or the work is done in tight areas. The cost of ground or catch tarps is minimal.

135. Waste disposal costs are low because the waste consists only of paint chips, rust, and mill scale. The waste from removing leaded coating systems probably will be classified as a hazardous waste. With 1 to 4 oz of coating per square foot, and disposal costs of $250 to $450 per ton, the estimated cost of disposal is $0.01 to $0.06/sq ft.

136. The dust generated during power tool cleaning to bare metal is relatively low and usually does not attract attention. The probability of exceeding NAAQS outside the work area is extremely low, and even lower if vacuum power tools are used. Practically, air monitoring is rarely performed. Workers will be exposed above the PEL when removing lead paints using unshrouded power tools; therefore, an average cost of $1.50/sq ft should be used in cost calculations. Proper use of vacuum shrouded power tools, especially on flat surfaces, should result in minimal worker exposure, certainly below the PEL and even below the Action Level. Not enough field experience has been reported, especially on structural steel, to state authoritatively that exposure above the PEL will not occur. Because OSHA regulations require initial worker monitoring and medical surveillance (blood lead analysis) for employees exposed above the Action Level, an average cost of $0.50/sq ft should be used for vacuum shrouded power tools.

137. In conclusion, unshrouded power tool cleaning to bare metal costs an average of $9.00/sq ft ($6.00 for cleaning and painting, $1.00 for containment and disposal, $1.50 for worker health, and $0.50 for overhead/miscellaneous). The average cost of vacuum shrouded power tools

actually will be less because the savings in containment and worker health will more than offset the additional cost of the vacuum system.

Chemical Stripping

138. The cost of chemical stripping is estimated as follows:

	Range	Average	To SP-10
cleaning and painting	$2-$4	$2.50	$4.00
containment	0-2	1.00	2.50
disposal	0-1	0.50	0.75
environmental monitoring	0-2	0.00	0.00
worker health	0-2	0.50	0.50
overhead/miscellaneous	0-2	0.50	0.50
total	$2-$13/sq ft	$5.00/sq ft	$8.25/sq ft

139. Surface preparation costs are based on being able to remove all the coating with one application of the stripper. Application of the stripper and removal by hand methods can be performed at a rate of 50 to 100 sq ft per hour. Coverage rates vary; typical rates are 15 to 30 sq ft per gallon. The cost of the stripper is $10 to $15 per gallon (some of the "environmentally safe" strippers cost more than $20 per gallon but provide increased coverage). Using a labor rate of $25 per hour, the cost for coating removal is $0.50 to $1.50/sq ft. Spray application is possible and will increase the area that can be stripped in a day, but more labor is required for removal. Equipment costs for spray application, disposables, etc. must be included. For estimating purposes, an average cost for surface preparation is $1.00/sq ft. This is the same estimated cost as abrasive blasting and results in an estimated cost for cleaning and painting in the range of $2.00 to $4.00/sq ft.

140. Containment costs depend on the type of structure. The stripper and debris have a sludge-like consistency, and any water used for cleaning also must be controlled by the containment. The sludge is picked up manually with shovels. For ground level structures, a layer of plastic or a tarp on the ground will not be sufficient; a more substantial ground cover is needed. For example, the literature (Carroll, November 1992) describes one job in which containment around a ground storage tank consisted of 30-mil thick sheets of rubber glued and taped together and extending approximately 20 ft out from the tank; cinder blocks placed under the outer edge formed a berm around the tank. Containments in the air will have to be constructed with solid floors such as plywood and sealed in a manner so liquid will not drip through. Side tarps also may be needed to protect the material from drying out in the sun. Containment costs are $0.50 to $2.00/sq ft.

141. Disposal costs depend on usage rates of the stripper. Strippers have high solids content, and loss of solvent is partially counterbalanced by the paint removed; therefore, each gallon of stripper generates nearly 1 gal of waste. Practically, the recovery rate ranges from 0.5 to 1 gal of waste per gallon of stripper. The waste from removing leaded paints probably will be classified as a hazardous waste. Using 25 sq ft per gallon as the usage rate and a disposal cost of $400 per drum, the disposal cost ranges from $0.15 to $0.30/sq ft. Note that the stripper can be removed, or the surface washed, with high pressure/low volume spray. These units generate only a few tenths of a gallon of water per minute, which can be incorporated with the stripper debris. Therefore, no extra costs for separation and disposal of water is included in the cost estimate.

142. Environmental monitoring costs are minimal. No dust is generated during the stripping process, and air monitoring is not needed. Soil monitoring should be performed and will cost only a few cents per square foot.

143. Workers are exposed to some lead during the stripper removal process, but field data is insufficient to indicate whether or not the PEL would be exceeded. An average cost of $0.50/sq ft should be used for estimating purposes.

144. Chemical stripping removes only the paint. Removing mill scale and rust to achieve a Near-White Metal (SSPC-SP10) finish requires a second blasting step. The cost for the second blasting step was previously determined in the discussion of the cost of water blasting (see paragraph 124).

PART V: RECOMMENDATIONS

145 Recommendations for total coating removal and maintenance (spot) painting depend on the situation. Each method has its strengths and weaknesses; however, the following generalizations can be made.

Total Coating Removal

146. The most effective method for total coating removal is dry abrasive blasting, which is based on both technical capabilities and cost. Using recyclable abrasives is preferred because the waste generated is minimized. However, the number of contractors who own this type of equipment currently is limited and influences bid prices. Vacuum blasting is recommended on structures with a large percentage of flat steel, if proper attention is placed on proper operation of the equipment. Wet abrasive blasting with units that use a low amount of water is a viable alternative for structures close to the ground if the debris can be left in place and protected until all standing water has evaporated.

147. Wet methods such as water jetting and water blasting with abrasive injection is not recommended except on a limited basis on simple, low structures when chemical contamination is present, such as from salt. The main problem with methods that use a lot of water is construction of leak-proof containment to catch the water. However, water jetting or sodium bicarbonate blasting should be considered in areas around operating machinery when grit, which can get into bearings or electrical equipment, cannot be tolerated.

148. Economically, power tool cleaning to bare metal for total coating removal is a viable alternative. However, SSPC-SP11 is a relatively new specification. The appearance of the end condition is not well understood, and there have been problems with enforcement. The need to have a variety of tools and not just "make do" with the tools available on the job has caused difficulties in the field.

149. Chemical stripping followed by abrasive blasting appears to be an economically viable alternative, but with practical difficulties. One application of the stripper may not be sufficient to remove the paint, especially if an aluminum flake top coat is present. If all the coating cannot be removed in one application of the stripper, the process becomes more expensive. If only isolated spots, small areas, or a thin layer of material remains on the surface, pressure may be exerted to allow these remnants to be removed by abrasive blasting. Because the lead in the coating is concentrated in the primer, the blasting step is considered a lead paint removal job. All the regulations and precautions for dry abrasive blasting apply and would increase the cost significantly.

Maintenance Painting

150. Maintenance painting involves spot surface preparation of corroded areas or areas with loose paint, followed by spot application of primer, spot, or full intermediate coat, and spot or full top coat. The cost of the surface preparation is a significant cost of performing the work. The use of Brush-Off Blast Cleaning (SSPC-SP7) will not be much different from total coating removal.

151. The preferred alternative to SSPC-SP7 is cleaning the rusted areas to bare metal with power tools (SSPC-SP11), and cleaning the visually intact coating by hand or power tools (SSPC-SP2 and SP3). Containment requirements for SSPC-SP2 and SP3 will be an SSPC Class 5 or Class 4 containment, which also will suffice for power tool cleaning to bare metal in most situations. Therefore, this procedure will minimize containment and disposal costs.

152. Another alternative to consider is vacuum blasting, which is appropriate for structures with corrosion mainly on flat surfaces such as welds. When the amount of area needing cleaning is relatively small and is amenable to proper seal of the vacuum head, the increased costs of vacuum blasting is more than compensated for by the cost of constructing containment.

153. Water blasting is another technique worth considering for removal of loose paint, rust, and mill scale. In these situations, a surface-tolerant coating is used so rust inhibitors do not have to be used. The main impediment to water blasting is the potential need to collect the water. The loose material removed comes off in discreet chips, and few fines; and a filtering material that can remove these particulates should be sufficient. If the filtering material can be incorporated in the work area and the water allowed to run off, water blasting to remove loose paint, rust, and mill scale is technically and economically feasible. However, the cost becomes prohibitive if the water must be collected and tested prior to disposal.

154. Chemical stripping is not an alternative for maintenance painting because it does not locate areas with loose coating. However, chemical stripping should be considered when total removal of the paint is warranted, especially on relatively small areas such as on machinery, because the stripper can be applied to all surfaces with little difficulty.

155. In conclusion, the general recommendations made are for "standard" situations. A broad variety of surface preparation methods, including relatively new ones, are available and may be useful in a particular situation. Production rates in this report were obtained from contractors and owners and represent costs obtained on projects. These production rates include breaks, unproductive time because of the configuration of the structure, and certain assurances that the end surface conditions were met. Production data from equipment suppliers when tests were performed on flat plate or limited surface area (less than 100 sq ft) were not used.

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APPENDIX A: ACRONYMS AND ABBREVIATIONS

TERMS	ABBREVIATIONS
certified industrial hygienist	CIH
Comprehensive Environmental Response, Compensation, and Liability Act	CERCLA
cubic feet per minute	cfm
Environmental Protection Agency	EPA
feet	ft
gallon	gal
high efficiency particulate filter	HEPA
Housing and Urban Development	HUD
hour	hr
inch	in.
microgram per cubic meter	$\mu g/m^3$
micron	μ
millimeter	mm
minute	min
National Ambient Air Quality Standards	NAAQS
National Association of Corrosion Engineers	NACE
National Pollutant Discharge Elimination System	NPDES
Occupational Safety and Health Administration	OSHA
Office of Solid Waste and Emergency Response	OSWER
ounce	oz
parts per million	ppm
permissible exposure limit	PEL
pound	lb
pounds per square inch	psi
Resource Conservation and Recovery Act	RCRA
square foot	sq ft
Steel Structures Painting Council	SSPC
Superfund Amendments and Re-Authorization Act	SARA
surface preparation	SP
Total Suspended Particulate	TSP
Toxicity Characteristics Leaching Procedure	TCLP
U.S. Environmental Protection Agency	USEPA

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